SCIENTIFIC PAPERS.

A DISEASE OF THE BLACK LOCUST (ROBINIA PSEUDACACIA, L.).

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The black locust, *Robinia Pseudacacia*, is a tree grown extensively in this country and in Europe, as an ornamental tree, and in some sections for its wood, which ranks among the best known and valuable of the American timbers. It is a tree which has few enemies, but of the small number which do attack it several are very destructive. Of the insect enemies, the locust borer, *Cyllene robiniae*, Forster, is the most destructive.* It is responsible for the fact that the locust is not more universally grown for its wood, for it bores into the sound wood of living trees, completely riddling it with holes which spoil the wood for lumber.

The fungus diseases of the locust are, as a rule, not very destructive. *Aglaospora profusa* De Not., *Valsa ceratophora* Tul.† and several others are found on the twigs now and then. The wood of the trunk and branches is destroyed by *Polyporus rimosus*, Berk. This fungus grows on older trees in the eastern United States; it has been found from New York southward along the Alleghanies to Alabama and westward to Southeast Missouri. During the last year it was found in great numbers on the

* Jack, J. G. Notes on two troublesome borers. Garden & Forest. 5: 426. 1892.

Packard, A. S. Insects injurious to forest and shade trees. Bull. No. 7, U. S. Entomological Commission. 95. 1881.

† Sargent, C. S. Silva of North America. 3: 38. 1892.

southern shore of Long Island, N. Y., where it destroyed the wood of many of the fine old trees, which form one of the attractive features of the boulevards.* Every severe windstorm breaks off some of the large branches of affected trees, and oftentimes the entire crown, so that the whole tree must be removed.

Polyporus rimosus attacks the locust after the trees have formed some heartwood in the larger branches, *i. e.* when the trees are about six inches in diameter. From this time on one will find the mycelium of the fungus growing in the heartwood, and with increasing frequency as the trees grow older. Infection takes place through older branches, and through the tunnels made by the locust borer. Wounds are frequent in older trees because of the extremely brittle nature of the branches. The fresh wounds are favorable points for the germination of the spores, and it is an easy matter to find all stages, from trees recently infected, to trees where the whole side of a trunk has evidently been infected from one branch.

The wood of the locust is very hard and resistant, and has been used for many years to such an extent that it ranks among the most valuable timbers. The following description of the wood is given by Sargent:† "The wood is heavy, exceedingly hard and strong, close grained and very durable in contact with the ground. It is brown or more rarely light green with pale yellow sapwood composed of two or three layers of annual growth only; . . . The specific gravity of the absolutely dry wood is 0.7333, a cubic foot weighing 45.70 pounds."

Several rows of very large ducts mark the beginning of the spring wood. These ducts are remarkable for the large number of thylloses which completely fill the lumen; this feature distinguishes the wood from that of the closely

* The writer is indebted to Mr. A. Wagstaff of Babylon, L. I., for permission to cut an affected tree on his grounds.

† Sargent, C. S. Silva of North America. **3**: 40. 1892.

allied honey locust (*Gleditschia triacanthos*). Between the ducts the thick-walled short wood fibres are massed closely together with here and there a group of wood parenchyma cells. The medullary rays are numerous, and many extend continuously out to the sapwood. They are rather obscure when viewed with the naked eye.

The changes which the mycelium of *Polyporus rimosus* brings about in the locust wood are very striking. The hard resistant wood is transformed into a soft yellow mass which, when wet, is more or less spongy. The almost flint-like character of the sound wood is wholly gone in completely decayed wood, which can be cut almost like cheese. On Plate 1 a cross-section of a locust trunk is shown in which parts of the heartwood are destroyed. The tree from which this section was taken measured 9 inches in diameter at this point. A sporophore grew 20 feet from the ground, and the decay extended up the trunk from this point for 3 feet, and down the trunk 8 feet 5 inches. It will be noted that the central part of the heartwood is completely rotted, and that the decay extends outward in radial lines. When split longitudinally it will be seen that these radial lines form the edges of sheets of decayed wood which are from 1 to 2 inches in width vertically; they occur every few inches in the vertical section, and extend out from the central decayed mass toward the bark, which they reach in many cases. Every one of these sheets of decayed wood has a more or less distinct red core almost the size of a small lead pencil, composed of wholly disintegrated wood held together by the mycelium of the fungus; the whole core can be lifted out intact. Extending upward and downward from this core the yellowish-brown wood is discolored, becoming yellow orange * nearest the core and very light straw color farther away. As the cores grow outward, the hyphae composing them grow through the

* See yellow orange shade No. 1, Milton Bradley color scale.

cambium layer and the living bark, killing them both. A large mass of hyphae forming a compact red brown felt then develops in the space left when the live surrounding wood increases outward. Such a space, filled with the brown felt, can be seen near the upper end of the figure on Plate 1, immediately under the bark.

On a tangential section of a diseased trunk the decayed sheets stand out as lens-shaped masses, the round core in the centre surrounded by yellow wood gradually merging into the yellow-brown of the heartwood. The lens-shaped areas are of all sizes from 2 inches high and ½ inch broad to the size of a pinhead, which can be recognized only by their differing in color from the surrounding wood. These sheets of decayed wood grow in height, and in the course of time join in a vertical direction; new sheets form between the primary ones, and ultimately a tangential union takes place. The whole wood is then completely decayed.

The sheets do not begin to form until a part of the heartwood is decayed. In an endeavor to explain this rather singular method of spread through the wood, one would at first sight suppose that the core of each sheet had taken the place of the remnant of a small branch, which had been healed over as the tree grew in diameter. This seems very plausible from the fact that the decay extends so rapidly in what appears to be a predetermined path, *i. e.*, a path extending through the sound wood on either side, through which the fungus hyphae can grow more readily than through the sound wood. It was found that this could not be the case, because there are not enough small branches in the sound wood to account for the many radial lines along which the fungus traveled. In seeking for another explanation it was found that the medullary rays are probably the paths selected in this case, as in so many other trees.

The manner in which fungus hyphae spread through a piece of timber is determined to some extent by the struc-

ture of the timber. Wood which has large vessels, prominent medullary rays, resin channels, or the wood elements of which are large-lumened and thin-walled, will be penetrated throughout its entire mass more readily than wood where those natural channels are absent, or which has short thick-walled wood elements. As a rule it was found that the course of hyphae in all the timber so far examined is first through the medullary rays and vessels, from which points individual hyphae penetrate the woodcells adjoining; in other words it appears that growth directly through a solid mass of wood rarely takes place, and when it does so it is a very slow process.

The wood elements of the locust are short, thick-walled and resistant, and are penetrated by the hyphae very slowly. The medullary rays on the other hand are large and continuous, and are composed of small comparatively thin-walled parenchymatous cells. These are rapidly invaded and destroyed by the hyphae, and it is through them that the mycelium extends outward from the point of infection. This accounts for the peculiar sheets. The fungus advances through the large medullary rays, and from them the hyphae grow laterally and vertically into the surrounding vessels and wood cells. Progress laterally is made difficult, because the hyphae have to bore their way through the solid walls of the wood fibres and it, therefore, goes on slowly. Progress longitudinally is more rapid, because here the large ducts permit of a rapid advance up and down, and even the woodcells are more easily reached. It will readily be comprehended how a spread of this kind through wood of the nature of the locust must tend to form sheets of the kind described. One finds similar cases among some of the oaks, but not to such a marked extent, for there the woodcells are not so resistant nor so closely packed together.

A piece of wood taken from the vicinity of one of the sheets will show changes as represented in Plate 3. The

medullary rays when invaded by the mycelium are rapidly destroyed. They can be recognized as brown lines extending outward into the sound wood (Plate 3, m). The large conspicuous vessels are completely filled with brown hyphae, which have riddled the walls of the thylloses, but have not entirely absorbed them. Passing toward the more decayed parts one finds the small woodcells attacked, here and there, so that small groups lie embedded in a felt of hyphae. Even these gradually disappear (see the middle of Plate 3) and one has only remnants of the large ducts. The walls of the latter appear to be the most resistant parts of the wood, and even in completely decayed wood, such as is represented at the top of Plate 3, one can always recognize the place of the former ducts by separate pieces which the fungus has not been able to destroy. The walls of the thylloses are similarly resistant, and can be recognized, together with the walls of the ducts (Plate 3). Both stain deep red with phloroglucin and hydrochloric acid, showing that they have suffered no change whatever.

The manner in which the walls of the woodcells are dissolved varies in different parts of the trunk. The first change noticeable in both medullary ray cells and the woodcells is the disappearance of the yellow-brown coloring matter. This is followed by the solution of the middle lamellae of the medullary ray cells and the destruction of the lignin elements of the latter, leaving the white cellulose fibres free from one another. These in turn soon disappear completely, and their place is taken by masses of brown hyphae. Similar changes take place in the wood here and there, resulting at first in the conversion of large masses of wood fibres to cellulose; these in turn are completely disintegrated. In the more common form of destruction the woodcells are not converted into cellulose. The hyphae penetrate the woodcells in all directions, riddling the walls with larger and smaller holes, so that they gradually break into small isolated pieces, which can be observed embedded

in the brown mycelium for some time after all semblance to wood structure has been lost. The smallest pieces were shown to be wood, which indicates that the destruction is one which does not pass through the cellulose stage.

The mycelium in the newly invaded parts of the wood consists of thinwalled, almost colorless hyphae, which branch frequently, and penetrate the walls of the wood-cells in all directions. The older hyphae are thickwalled, and dark brown. They fill the large vessels and the spaces formerly occupied by the medullary rays, making a dense network. As the hyphae grow outward through the older wood, they form the peculiar sheets already described. Now and then the hyphae forming the core of a sheet, reach the cambium layer and spread from this point in all directions, killing the living bark and wood, as has been pointed out. A thick felt of hyphae forms in the space under the bark, and at times breaks or grows through the bark, appearing as a small knob on the outside of the trunk. These knobs are light red-brown, and are very hard and smooth. They gradually increase in size, and when about an inch in thickness, pores form on the lower side.

The young sporophore increases in size, and continues to do so for many years. The largest seen was about 16 inches in diameter laterally, and 8 inches from front to back. The mature form consists of one or more broad shelves, the top of which meets the lower side at an angle of about 30°–35° (Plate 2). The shelves are usually almost twice as wide laterally as from front to back. The upper surface in older specimens is composed of a number of ridges which are very distinct in the younger part, but become almost obliterated as the sporophore grows older. The most recent layer forms the front rounded edge of the sporophore, and is characterized by the very smooth surface, which extends over the edge onto the lower side. In some sporophores it is very

light brown, and somewhat villous, in others it is entirely smooth, even shining as if polished, and dark brown. The older parts of the upper surface are dark brown, almost black, and are broken into many small pieces by numerous fissures. Many old sporophores have a jagged, extremely rough surface because of this fissuration. Lichens and mosses frequently cover the older parts.

The lower side of the sporophore is dull red brown.* The pores are exceedingly fine, so that they can scarcely be distinguished with the naked eye, measuring on the average $108 \times 143\ \mu$; the dissepiments are about $108\ \mu$ in width. The interior of the sporophore is light brown, with evident though imperfect indication of stratification. The pores are continuous through several layers, remaining open for two or three years. They then become plugged at the base by the growth of hyphae from the walls of the hymenium. The plugging begins here and there in a particular layer and goes on irregularly. That the hyphae of the entire sporophore remain active is shown when parts of the sporophore are broken off, for then vigorous growth starts all over the broken surface, and in the course of a year one or more new sporophores have started, which gradually cover the broken surface and give the whole mass a peculiar appearance.

The hymenium consists of short club-shaped basidia which bear four spherical brown spores, which appear to ripen very rapidly. They are discharged into the pores, and can be noted escaping from the openings in clouds, particularly on moist days. During June and July active discharge was going on. Cystidia are absent from the hymenium; the paraphyses, in the earlier stages, project out into the pores for a short distance, and not infrequently masses of spores are collected about their tips. A very striking fact is the large number of spores which never

* The color approximating an equal mixture of yellow orange shade No. 1, and yellow orange dark, Milton Bradley color scale.

leave the pores, but become imprisoned in the latter, by the ingrowing hyphae. The sporophores were found only on living trees. Their number varied considerably, from single large individuals on younger trees to thirty and forty on older trees, where they grow out on the smaller branches, in the extreme tree-tops.

The characters above given agree well with the description given for *Polyporus* (*Fomes*) *rimosus*, Berk. This fungus was described by Berkeley as growing on logs in Demarara, British Guiana. It is evidently closely related to *Polyporus igniarius* (L.) Fr., on the one hand, and *Polyporus fulvus*, Fr. on the other, differing from both in the extremely hard cracked upper surface, from which it derives its name; from the former, also, in the texture and structure of the internal parts and in its form, which so far as seen never approaches the globose, hoof form. Its color readily distinguishes it from *Polyporus fulvus*, Fr.

As this fungus is essentially a wound parasite, preventive measures can be adopted by caring for the broken branches and other wounds. When but one tree of a group is infected, that tree ought to be cut down and burned so as to prevent infection of the other trees. Where possible the sporophores should be destroyed.

The mycelium of *Polyporus rimosus* does not grow in the wood of the locust after it is cut from the living tree. Diseased locust wood when used for posts does not continue to rot after it is placed in the ground. The fact that the mycelium ceases to grow in the wood after it is cut from the tree, or even after the death of the tree, suggests that the conditions which exist within the trunk of a live tree must be essentially different from those present after death.

There must be some factors which favor the growth of the mycelium while in the wood of the standing tree which are changed or entirely inoperative after the tree is cut down. It is well known that many kinds of wood are

very susceptible to the attacks of timber-destroying fungi while they are still parts of living trees, but as soon as they are cut from the trees not only does all further growth of that particular fungus cease, but the wood seems to be more or less immune for long periods to the attacks of the fungi which attack dead wood. Notable examples of this kind are the woods of the bald cypress and its near allies, the big trees, incense cedar and the various species of red cedar. The heartwood of all of these trees is destroyed (in some instances 90% and more of the living trees are affected) by fungi which do not grow after the wood is cut from the tree. Other trees, for instance the pines, have similar enemies, which grow only on live trees. The cessation of growth may possibly be due to the different moisture content of the wood of live trees, but this cannot be the sole factor, for felled trees do not begin to dry for long periods after cutting. The gases found in live trees may be different from those in the dead tree, both as to their composition and their tension. That there is considerable difference in this respect is shown by the readiness with which the fruiting organs of many of these fungi can be induced to form wherever a wound is made, admitting air.* A further factor which may be of a determining nature, is found in the products formed in the heartwood when exposed to the outside air; these are often made evident by a darkening of the wood. Differences in temperature probably occur. The intrinsic difficulties found in determining the physical condition of the wood while in a live tree do not allow of any more definite statement than those made above.

In this connection, the question arises, what are *Polyporus rimosus*, and the other fungi which grow on live trees, but not on dead wood of the same trees? Their substra-

* von Schrenk, H. Some Diseases of New England Conifers. Bull. No. 25, Div. Veg. Phys. & Pathology U. S. Dept. of Agriculture. 48. 1900.

tum is dead material in the ordinary sense of the term, for the live part of a tree, as determined by protoplastic cell contents, or their products, starches and oils, extends inward from the bark but a short distance (in the black locust the outermost 15–25 annual rings may be considered alive) differing with the individual and the tree. Hence these fungi are not parasites. As saprophytes, they must be considered such in a special sense, for although they grow on a dead substratum they nevertheless are unable to do so except under very special conditions. The fungi which Tubeuf * includes under hemisaprophytes differ from such a form as *Polyporus rimosus* in that they frequently grow and fructify on dead wood, at least with greater readiness than this fungus.

EXPLANATION OF PLATES.

Plate 1. — Cross-section of the trunk of a living black locust (*Robinia Pseudacacia*) cut at a height of 23 feet from the ground. The heartwood has been destroyed by the mycelium of the *Polyporus rimosus;* a sporophore of the latter appears at the one end of the section, (about ⅓ natural size).

Plate 2. — *Polyporus rimosus,* growing on a living black locust (*Robinia Pseudacacia*), (about ⅓ natural size).

Plate 3. — A transverse section of much decayed wood of the black locust showing the gradual manner in which the wood is being destroyed by the mycelium of *Polyporus rimosus: m,* medullary rays; v, large vessel.

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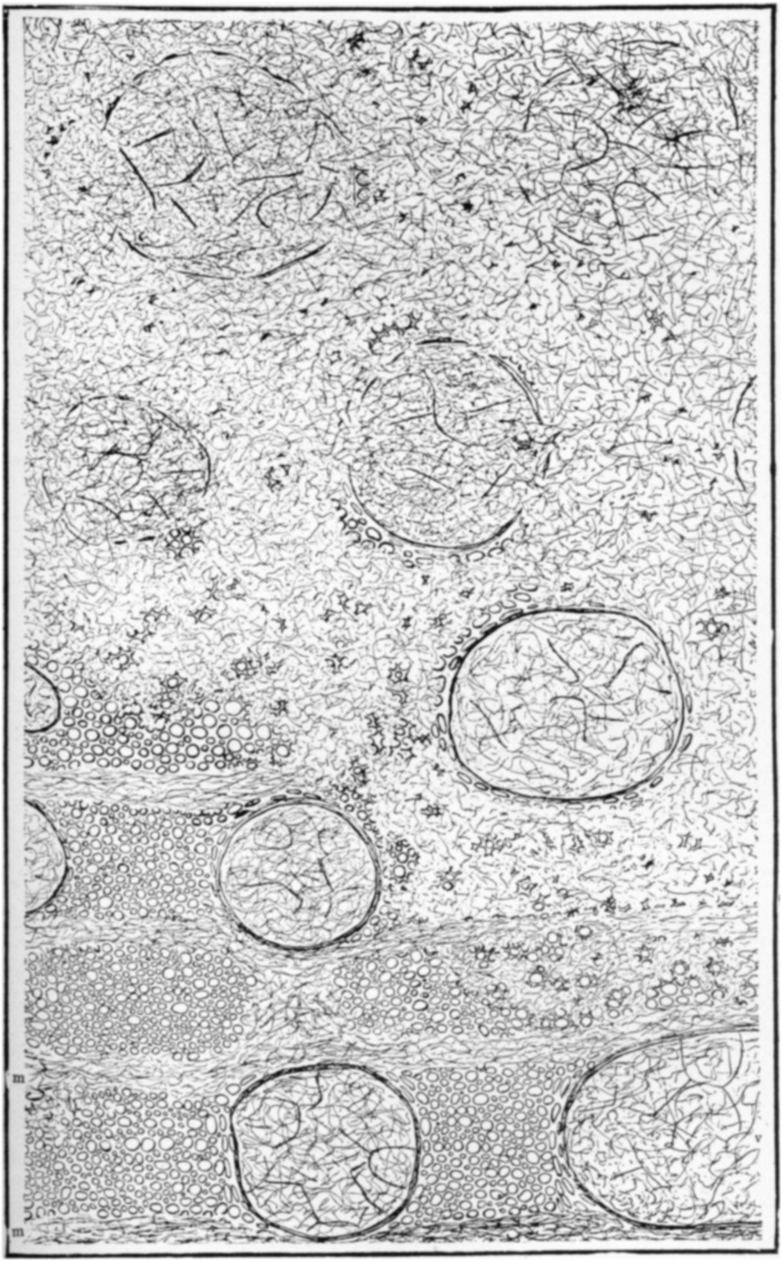
* Tubeuf, Carl Freiherr von. Pflanzenkrankheiten. 8. 1895.

SECTION OF A LOCUST TRUNK, SHOWING DECAYED WOOD IN THE CENTRE.

POLYPORUS RIMOSUS, ON LIVING LOCUST.



LOCUST WOOD, ATTACKED BY POLYPORUS.